INSTRUCTION BOOK FOR

BIRD

MODEL 43
RF DIRECTIONAL
THRULINE® WATTMETER

Also Covers Models
4430/31, 4521-27

LIMITED WARRANTY

We are proud of the high quality of our product and we warrant to the original purchaser that each new instrument of our manufacture will for a period of one year after original shipment be free from defects in material and workmanship under normal and proper operating conditions and that properly used during such period it will perform in accordance with our applicable specifications.

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Warranty returns must be first authorized by the factory office and are to be shipped prepaid.

MODELS COVERED IN THIS INSTRUCTION BOOK

43
4430
4431
4521
4522
4523
4525
4526
4527

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MODEL 43
RF DIRECTIONAL
THRULINE® WATTMETER

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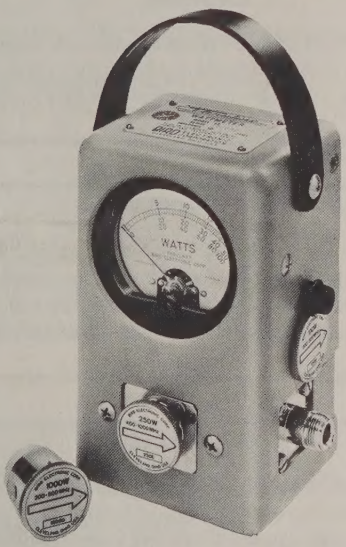

BIRD

Electronic Corporation

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SAFETY PRECAUTIONS

The following are general safety precautions that are not necessarily related to any specific part or procedures and do not necessarily appear elsewhere in this publication.

Keep away from live circuits.

Operating personnel must at all times observe normal safety regulations. Do not replace components or make adjustments inside the equipment with the high voltage supply turned on. Under no circumstances should any person reach into the enclosure for the purpose of servicing or adjusting the equipment except in the presence of someone who is capable of rendering aid. Personnel working with or near high voltage should be familiar with modern methods of resuscitation.

The following will appear in the text of this publication and is shown here for emphasis.

CAUTION

Do not drop the THRULINE® or its elements or subject them to hard blows. The microammeter is shock mounted in the wattmeter housing, but its delicate mechanism may be damaged by severe impact.

WARNING

When operating this equipment in conjunction with RF power of 200 watts or higher, the potential of the center conductor of the RF line section will be 100 volts or higher. Do not contact the center conductor. If cleaning becomes necessary, shut off the RF power.

CAUTION

When making low reflection readings using two elements, take care to insert the lower reading element so that it senses reflected power only. Do not rotate the lower reading element in the socket so that the unit is subjected to forward power. This will result in damage to the Plug-In Element, the microammeter, or both.

WARNING

When using dry cleaning solvents, provide adequate ventilation and observe normal safety precautions. Many dry cleaning agents emit toxic fumes that may be harmful to your health if inhaled.

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43 THRULINE® WATTMETER

INTRODUCTION

PURPOSE AND FUNCTION

This instruction book covers and is written describing the use and operation of the basic Model 43 THRULINE® Wattmeter. These instructions also apply to other units that are very similar to the Model 43 in electrical characteristics and operation.

These different models and their variations are also included in this book; however, the operational procedures and, in most cases, the electrical specifications of the Model 43 apply to these units. The basic difference in the majority of these units is physical, being panel rack mounted versions of the Model 43 THRULINE®. However, two of the units are similar in appearance but differ in as much as they have an RF sampler port included.

All differences pertinent to these units can be found in the "Difference Data Sheets", in the back of this book.

The Model 43 THRULINE® Wattmeter is an insertion type RF wattmeter, designed to measure power flow and load match in 50 ohm coaxial transmission lines. It is intended for use on CW, AM, FM and TV modulation envelopes, but not pulsed modes. The Model 43, when used in 50 ohm applications, has an insertion VSWR of less than 1.05 to 1 up to a frequency of 1000MHz. The meter is direct reading in watts, expanded down scale for easy reading and is graduated 25, 50 and 100 watts full scale. The power ranges used are determined by the Plug-In Elements, which fall in ten frequency band groups covering from 2-2300MHz plus additional special elements in various power and frequency ranges, see Section III - Operating Instructions. Further characteristics may be found on the Specification Sheet, Page v.

PERFORMANCE CHARACTERISTICS AND CAPABILITIES

The Model 43 THRULINE® Wattmeter is a portable unit contained in a die cast aluminum housing, with a formed metal enclosure on the back which is easily removed. Included with the unit is a leather carrying strap, four rubber shock feet on the base, and four rubber bumpers on the back, which allow the Model 43 to stand or lie flat when used. For additional protection, the microammeter is specially shock mounted. A slotted screw is provided on the lower front face of the meter for zeroing the pointer. Below the meter, the RF line section face protrudes slightly from the wattmeter housing with the Plug-In Element socket in the center.

A shielded cable connects the microammeter to the dc jack which is attached to the side of the RF line section casting. This cable, nearly three feet long, permits removal of the RF line section from the wattmeter housing. Meter connections may be maintained with any installations outside of the housing. This permits permanent additional installation to be made. See Section I - Installation.

Inside the dc jack assembly, there is a filter capacitor which shunts the meter circuit to prevent misreadings caused by stray RF energy existing in the Plug-In Element. Mounted on the dc jack is a phosphor bronze spring finger, which pro-

trudes through a lateral hole and into the Plug-In Element socket of the RF line section. The finger has a button on its end which mates with the contacts of the Plug-In Element. The silver plated brass RF line section is precision made to provide the best possible impedance match to the coaxial RF transmission line in which the Model 43 is inserted. The ends of the line section are nested in mating slots to provide additional mechanical support.

At each end of the line section are Bird Quick-Change type RF connectors, which may be quickly interchanged with any other Bird "QC" connector by removing the four screws on the mounting flanges. The wattmeter housing does not interfere with any connector changes.

To make measurements, the cylindrical shaped Plug-In Element is inserted into the line section socket and rotated against one stop. A small catch in the upper right hand corner of the casting face presses on the shoulder of the Plug-In Element to keep it in proper alignment and assure a good contact with the dc jack and between the lower edge of the element and line section body. On diametrically opposite sides of the Plug-In Element body are contacts to provide dc pickup in either direction. These contacts make connection with the spring finger of the dc jack only when the Plug-In Element is in the precise forward or reverse position, and with the index pin on the element on the lower level of the line section casting face aginst its respective stop.

SPECIFICATIONS FOR MODEL 43 THRULINE® WATTMETER

This specification also includes data covering similar Models 4430, 4431, 4521, 4522, 4523, 4525, 4526 and 4527. Any specificatins pertaining to a particular model will be found in the "Difference Data Sheets" located at the back of this book.

Impedance (All Models) ..... 50 ohms nominal

Insertion VSWR

All Models except 4431	Less than 1.05:1 maximum
4431	Less than 1.07 at coupling of less than 30dB

Connectors

RF Sampling	Female BNC
Primary Line	Bird "QC" Female N Normally Supplied

Continued

Power and Frequency Range

Models 43, 4521/22/23/25/26 ..... 100MW-10000W full scale direct reading in watts, frequency range from .45 to 2300MHz. Select elements from Tables 1, 2, 3, 4 and 6 found in Section III.

Models 4430 & 4527 ..... 1000W maximum 2-200MHz
500W maximum from 200-512MHz

Model 4431 ..... 5000W maximum from 2-30MHz
1000W maximum from 30-10000MHz
(applicable only if coupling used is less than 30dB).

Accuracy (All Models) ..... ±5% of full scale

Dimensions

Models 43 & 4430 ..... 3⅝"L x 4"W x 6⅞"H
(92.1 x 101.6 x 174.6mm)

Model 4431 ..... $3\frac{27}{32}$"L x 4"W x 6⅞"H
(97.6 x 101.6 x 174.6mm)

Weight

Model 43 ..... 3 lbs. (1.36kg)
Model 4430 ..... 3¼ lbs. (1.47kg)
Model 4431 ..... 3½ lbs. (1.59kg)

Operating Position ..... Any

Finish (All Models) ..... Light navy grey baked enamel

RF Coupling

Models 4430 & 4527 ..... Approx. −53dB from 512MHz down to 10MHz decreasing to −70dB between 10 & 2MHz

Model 4431 ..... Adjustable, 15-70dB
(See "Difference Data Sheet")

Insertion Loss (Model 4431)

2-512MHz ..... 0.1dB maximum
512-1000MHz ..... 0.2dB maximum*

*Above listed specifications are applicable only if maximum coupling used does not exceed 30dB. This requires a minimum decoupling of four full turns counter-clockwise (CCW) above 200MHz and a minimum decoupling of seven full turns (CCW) above 800MHz.

SECTION I - INSTALLATION

1-1. PORTABILITY

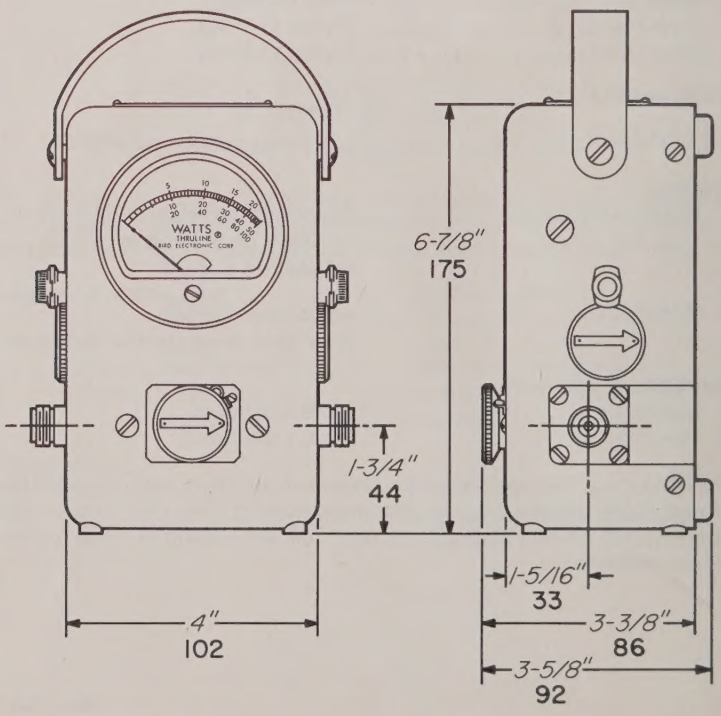
1-2. The Model 43 is a portable instrument, and the housing is not designed for fixed mounting, see Figure 1-1. A strap is provided for carrying purposes.

CAUTION

Do not drop the THRULINE® or its elements or subject them to hard blows. The microammeter is shock mounted in the wattmeter housing, but its delicate mechanism may be damaged by severe impact.

1-3. While transporting the THRULINE® it is best to reinsert the original dust plug, or a Plug-In Element with the arrow pointed upward, in the measuring socket, and secure with the catch. This will shunt the meter circuit and serve to protect the meter by dampening needle action during handling or shipping. Also, secure spare Plug-In Elements in their receptacles with the pivoting knob clamps; just insert the element to seat and twist knob one-quarter turn to hold. Handle the Plug-In Element with care at all times. Calibration could be disturbed if they are dropped.

Figure 1-1. Model 43 THRULINE® Outline Drawing.



1-4. CONNECTIONS

1-5. Insert the Model 43 THRULINE® in coaxial transmission lines of 50 ohms nominal impedance. It is indifferent to which respective side the power source and the load connections are made. If cables other than 50 ohm type are used, a mismatch will occur causing probable serious inaccuracies in readings. However, if a mismatch cannot be avoided, the results may be calculated, see 3-33, Impedance Mismatch. We strongly urge that you avoid this condition.

1-6. The Model 43 is normally supplied with two Female N type connectors which are of the Bird Quick-Change design. Other "QC" connectors are available as listed:

Male N	Female BNC
Female HN	Male BNC
Male HN	Female LC
Female C	Male LC
Male C	Female LT
Female UHF	Male LT
Male UHF	Female TNC
7/8" EIA Air Line	Male TNC

1-7. These may be purchased from Bird Electronic Corporation as required. See Section V - Replacement Parts List.

1-8. The above connectors are quickly changed by removing the four #8-32 pan head machine screws from the corners of the connector flange, and pulling straight out. Reverse this procedure to attach connector, making sure the center contact pin aligns properly with the socket.

1-9. REMOTE INSTALLATION

1-10. The RF line section can be removed from the meter housing for remote installation. To remove the line section from its housing:

a. Unscrew the four #8-32 flat head machine screws holding the back cover.

b. Grasp the cover by the side filler tabs and pull directly backwards. The back cover assembly will come off with the speed nuts remaining attached.

c. Remove the two #10-32 oval head machine screws on the front of the housing.

d. Slide the line section backwards out of the housing. Do not loosen the two oval head screws on the sides of the housing in line with the meter. These hold the meter supporting shock ring in place.

e. Substitute the cable which attaches the line section to the meter with a sufficient length of cable to make the remote installation.

f. To replace the RF line section, reverse the above listed procedures.

1-11. It may be desirable to have two or more line sections permanently installed in continuous operating equipment. In this case, one set of elements and one

meter may be used to measure several RF transmission lines without interruption of RF lines for insertion of the THRULINE®. Additional RF line sections (Figure 1-2) are available.

Figure 1-2. Installation Drawing, RF Line Section.

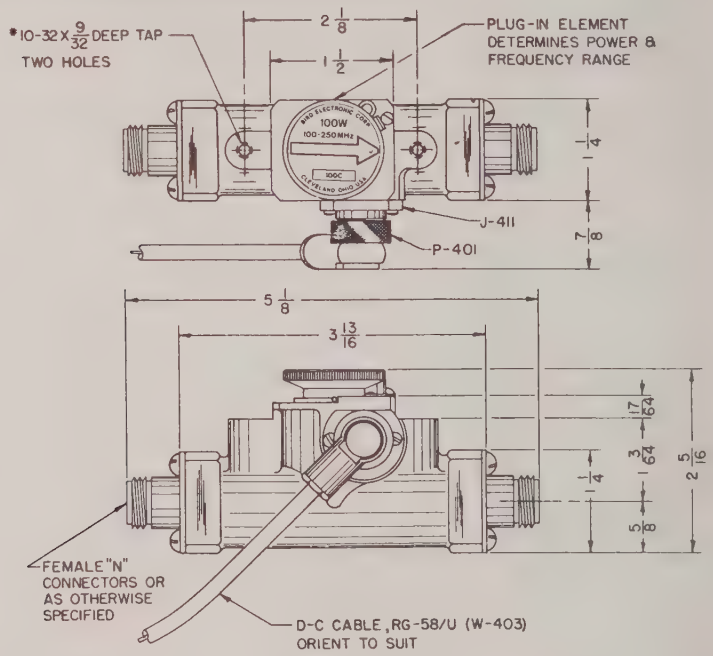
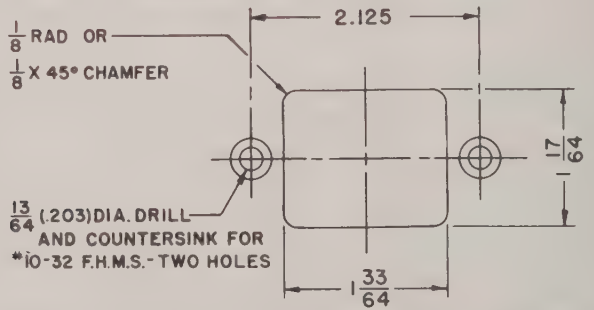


Figure 1-3. Panel Cut for Mounting RF Body.



1-12. The RF line section of the Model 43 blends very readily to panel type mounting. A layout for the panel mount cut is given in Figure 1-3. The thickness of the panel should be about ¼". On panels less than this, build up the thickness with pads or washers to achieve a flush-face mounting. Cable connections are simplified because the RF line section may be mounted in any convenient direction. Attach the line section so that the finger catch is in the most accessible position.

SECTION II - THEORY OF OPERATION

2-1. TRAVELLING WAVE VIEWPOINT

2-2. The best way to visualize the THRULINE® idea is from the Travelling Wave viewpoint on transmission lines, which illustrates that the voltages, currents, standing waves, etc., on any uniform line section are the results of two travelling waves:

a. The Forward Wave travels (and its power flows) from the source to the load. It has an RF Voltage E_f and current I_f in phase, with $E_f/I_f = Z_o$.

b. The Reflected Wave originates by reflection at the load, travels (and its power flows) from the load back to the source and also has an RF voltage E_r and current I_r in phase, with $E_r/I_r = Z_o$.

c. Note that each component wave is mathematically simple, and is completely described by a single figure for power, for instance:

$$W_f = \text{Watts Forward} = E_f^2/Z_o = I_f^2 Z_o = E_f I_f$$

$$W_r = \text{Watts Reflected} = E_r^2/Z_o = I_r^2 Z_o = E_r I_r$$

2-3. Z_o is the characteristic impedance of the uniform line, and simplifies matters by being nearly a pure resistance, usually 50 ohms, for useful lines. The main RF circuit of the THRULINE® is a short piece of uniform air type line section, whose Z_o is 50 ohms, in which accurate measurements may be made.

2-4. COUPLING CIRCUIT

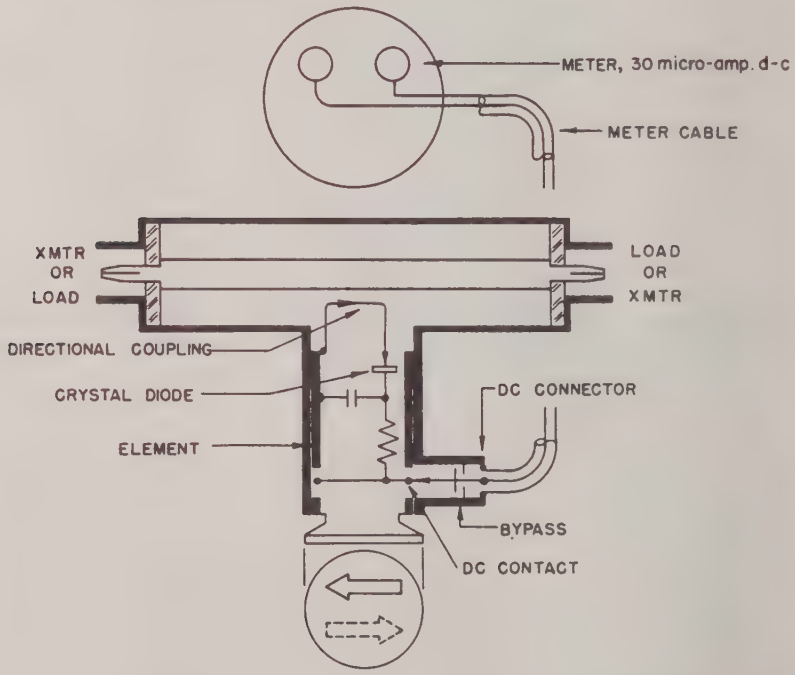
2-5. The coupling circuit which samples the travelling waves is in the Plug-In Element. The circuitry of the element and its relationship to the other components of the THRULINE®, are illustrated in the schematic diagram, Figure 2-1. Energy will be produced in the coupling circuit of the element by both mutual inductance and capacitance from the travelling RF waves of the line section. The inductive currents will, of course, flow accordingly to the direction of the travelling waves producing them. The capacitive portion of these currents is naturally independent of the direction of the travelling waves. Therefore, assuming that the Plug-In Element remains stationary, it is apparent that the coupling currents produced from the waves of one direction will add in phase, and those produced from waves of the opposite direction will accordingly subtract in phase. The additive or ARROW direction is, of course, assigned to the forward wave.

2-6. The electrical values of the element circuits are carefully balanced and so designed that the inductive current produced from the reverse wave will cancel its portion of the capacitive current almost completely. The result is a directivity always higher than 25dB, which means that the element is highly insensitive (nulled) to the reverse direction wave. By being highly directional, the THRULINE® Element is sensitive at either one of its settings, but to only one of the two travelling waves which produce standing waves by interference. THRULINE® measurements are also independent of their position along the standing waves. It may be said that the THRULINE® doesn't know, doesn't care, and doesn't need to care where it is along a standing wave.

2-7. STANDING WAVE RATIO VS REFLECTED/FORWARD POWER RATIO

2-8. As mentioned above, the THRULINE® technique uses the Travelling Wave viewpoint to measure most of the outstanding facts about transmission line operation. Another widely used and related viewpoint, is the Standing Wave, which is quite elaborately developed both mathematically and in existing equipment. This technique can be traced to the early development of slotted lines as tools of exploration.

Figure 2-1. Schematic Diagram - Element.



2-9. The slotted line is a standing wave instrument, and emphasizes this viewpoint. However, the slotted line is too long, too expensive if good, not portable, and slow in operation. These objections increase rapidly as the frequency drops below 1000MHz. Whereas the THRULINE® is surprisingly quick, convenient, and accurate by comparison. With the exception of phase angle reflection (distance, load to minimum) it tells everything a slotted line will.

2-10. The relationship between the Travelling Wave and the Standing Wave viewpoints are given in most high frequency textbooks.

SECTION III - OPERATION INSTRUCTIONS

WARNING

When operating this equipment in conjunction with RF power of 200 watts or higher, the potential of the center conductor of the RF line section will be 100 volts or higher. Do not contact the center conductor. If cleaning becomes necessary, shut off the RF power.

3-1. **GENERAL**

3-2. The apparent features of the THRULINE® equipment have been discussed in the Introduction, Theory of Operation, and in the Installation Sections. Measurements are made by the insertion and operation of the Plug-In Elements previously mentioned.

3-3. The elements determine the power range to be read on the meter scale, and the major markings (viz. 50W,100W, etc.) are the full scale power value for that element. Elements are also marked for frequency range. The transmitter frequency must be within the band of the element used. Elements are available according to those identified in the tables on Pages 13 and 14.

3-4. See 3-28, Frequency Response, of this Section for frequency band flatness, and performance of the elements outside of stated frequencies. Elements for additional ranges (power or frequency) may be ordered without returning the THRULINE® for calibration, since the RF bodies and meters are standardized, and are designed for a wide range of coaxial transmission power value and frequencies.

3-5. The ARROW on Plug-In Elements indicate sensitive direction; i.e., the direction of power flow which the meter will read. Arrow and Reverse are directional terms used in reference to the THRULINE® Element, and mean respectively the sensitive and null directions of the element. Rotate the element to reverse the sensitive direction. Forward and Reflected are directional terms used in reference to the source-load circuit. Note that the transmitter may attach to either connector of the THRULINE®. It makes no difference which external RF connection is selected, since the elements are reversible and the RF circuit is symmetrical end for end. Before taking readings be sure that the meter pointer has been properly zeroed under no-power conditions.

3-6. The THRULINE® used with a TERMALINE® resistor of proper power rating forms a highly useful absorption wattmeter. With the ARROW set toward the load, it is unnecessary to reverse because the reflected power will be negligible.

3-7. In cases where readings are being made when the meter unit is connected to an auxiliary RF line section body, always remove any measuring element from the unused RF line section. Otherwise, the dc circuit will be unbalanced or shorted according to the arrow position of the other element, causing inaccurate or no reading on the meter.

3-8. **LOAD POWER**

3-9. Power delivered to and dissipated in a load is given by:

$$W_l = \text{Watts Into Loads} = W_f - W_r$$

Where appreciable power is reflected, as with an antenna, it is necessary to subtract the reflected power from the forward power to get the load power. This correction is negligible (less than 1%) if the load is such as to have a VSWR of 1.2 or less. Good load resistors, such as TERMALINE®, will thus show negligible or unreadable reflected power.

3-10. VSWR scales and their attendant controls for setting the reference point have been intentionally omitted from the THRULINE® for two reasons.

a. Why make something similar to a hypothetical dc volt-ohm-meter with control pots for the voltmeter multipliers? Even more complications arise when diodes at RF are involved.

b. Experience using the THRULINE® on transmitter tune-up, antenna matching, etc.; i.e., on operating problems, shows that the power ratio ϕ is as useful in practice as the standing wave ratio ρ = VSWR.

3-11. A trial is suggested for a few days - forget VSWR and try thinking in terms of $\phi = W_r/W_f$ when the THRULINE® is used. It will be noted that even without bothering to calculate the ratio exactly, the two meter readings W_r and W_f give an automatic mental impression which pictures the situation. Thus, in an antenna matching problem the main objective usually is to minimize W_r, and anything done experimentally to this end is noted directly when the THRULINE® is turned to the reflected position. Furthermore, the ratio of readings even if only mentally evaluated, is a reliable guide to the significance of the remaining reflected power.

3-12. ρ VS ϕ AND ITS SIGNIFICANCE

3-13. Since there are definite simple relationships:

$$\rho = \frac{1+\phi}{1-\phi} \quad \text{and} \quad \phi = \left[\frac{\rho-1}{\rho+1}\right]^2 \quad \begin{array}{l}\text{where } \rho = \text{VSWR} \\ \text{and } \phi = \dfrac{W_r}{W_f}\end{array}$$

between standing wave ratio ρ and the reflected/forward power ratio ϕ indicated by the THRULINE®, the latter may be conveniently used to measure VSWR. The relationship is given in Figure 3-1 and 3-2.

3-14. Note that around $\phi = 10\%$, below which W_r will appear insignificant and may be hard to read, you are close to the commonly accepted lower limit $\rho = 2$, below which improved antenna match becomes less and less worthwhile in many systems. Experimentally by using the THRULINE®, it can be readily shown that reducing ϕ below 10% produces little gain in the way of increased W_l. TV transmitter antenna lines, and VHF omnirange transmitters are among those systems that require much lower levels of reflected power but for reasons other than simple power transmission. Note that in Figure 3-1, the very small level of reflected power; i.e., $\phi = .06\%$ corresponds to $\rho = 1.05$. With just a single element, detection of reflected power is possible down to about $\phi = 1\%$ ($\rho = 1.2$), providing W_f ap-

Figure 3-1. Percent Reflected Power VS VSWR (1.0:1.3).

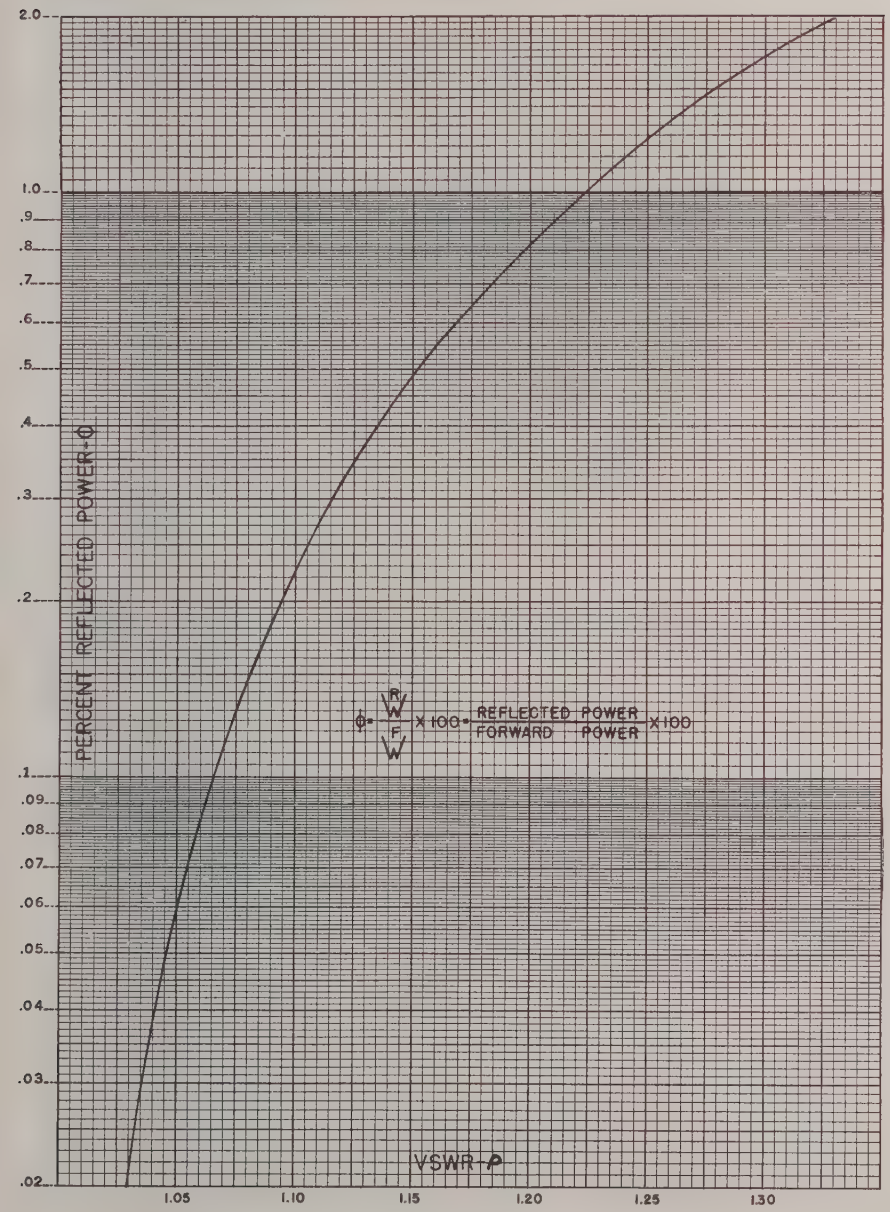
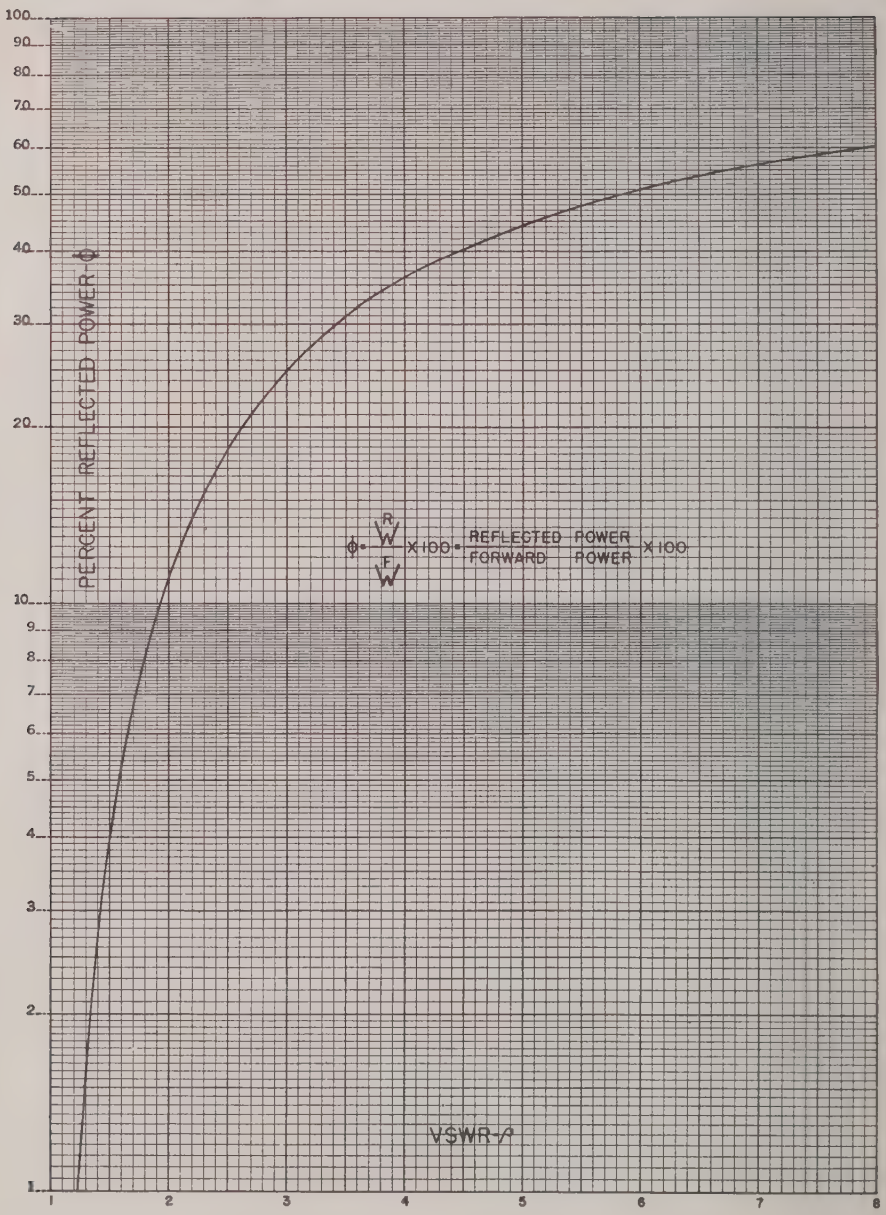


Figure 3-2. Percent Reflected Power VS VSWR (1.0:8.0).



proaches full scale. However, measurement is possible only down to about $\phi = 5\%$ ($\rho = 1.5$).

CAUTION

When making low reflection readings using two elements, take care to insert the lower reading element so that it senses reflected power only. Do not rotate the lower reading element in the socket so that the unit is subjected to forward power. This will result in damage to the Plug-In Element, the microammeter, or both.

3-15. Low reflection measurements may be extended below this with two elements. Say 80 watts are available, and you have 100 watt and 10 watt elements.

3-16. Measure W_f with the 100 watt element. Remove the 100 watt element and insert a 10 watt element. The ten watt element must be only in the reflected direction. ARROW toward transmitter. Insert and remove only this way. Now read W_r on the ten watt element.

3-17. In this case, measurement down to at least .5 watt reflected is possible which means to:

$$\phi = {}^{5}/_{80} \text{ say } .6\% \text{ or to about } \rho = 1.16$$

and detection of reflections is possible down to about .1 watt.

$$\phi = {}^{1}/_{80} = .00125, \text{ say } .1\% \text{ or to about } \rho = 1.06$$

3-18. Caution is necessary in the above method and preferably it should not be used with element ranges differing more than 10 to 1 although 25 to 1 can be used with extreme caution. With certain elements now available down to one watt full scale this method is usable with medium and low power transmitters.

3-19. **MEASUREMENT AND MONITORING OF TRANSMITTER POWER**

3-20. Little more need be said about this in view of the preceding load power discussion. The THRULINE® is useful for the continuous monitoring of transmitter output and is also helpful for the continuous monitoring of reflected power, for instance in checking intermittent antenna or line faults.

3-21. Like diode devices generally, the THRULINE® indicates the carrier component on amplitude modulation, with very little response to side band components added by modulation.

3-22. **TESTING OF LINES, CONNECTORS, FILTERS, ETC.**

3-23. The THRULINE® is highly useful for this purpose, and may be employed in several ways.

a. VSWR (Insertion) or ϕ (Insertion) may be measured with the line terminated in a good load resistor (TERMALINE®). The lower limits of sensitivity in this are given above under low reflection measurements.

b. ATTENUATION (Power lost by heat in the line) as well as VSWR (Insertion) and ϕ (Insertion) may be measured by inserting the unknown line between two THRULINE® units, or between two RF bodies used with one meter and one set of elements. (End of line to be terminated in a load resistor). This method applies also to insertion between the THRULINE® and a TERMALINE® Absorption Wattmeter. Very small values of attenuation require allowance for normal instrument errors. The correction may be determined by direct rigid connection of the THRULINE® units, or of the THRULINE®-TERMALINE® combination, in cascade. Slight juggling of zero settings is permissible for convenience in eliminating computation, provided readings are being taken fairly well up on scale.

c. ATTENUATION BY OPEN OR SHORT CIRCUIT METHOD. More clever by far than method (b) is one depending on the high directivity (null balance) to which the THRULINE® elements are held. They should, and do, exhibit good equality between forward and reflected readings when the load connector is open or short circuited. In this condition $\phi = 100\%$, the forward and reflected waves being equal in magnitude, and $\rho =$ infinity. Say that this is checked on open circuit, and then a length of line of unknown attenuation, also open circuited, is connected to the load connector. The ratio ϕ then shown is the attenuation in two passes along the line (down and back).

3-24. Expressed in dB, (using the equation $N_{dB} = \log W_f W_r$), the dB figure may be compared with published data for line type and length by rememebering to halve N_{dB}, or to double the line length, because twice the line length is actually being measured.

3-25. This measurement should be supplemented by one of ϕ (Insertion) as in (a) above, or at least by dc continuity and leakage checks, since the attenuation measurement alone can be in error from faults such as open or short circuits part of the way down the line.

3-26. Open circuit testing is somewhat to be preferred to short circuit, since the reference short (used to check equality initially) must be good, and because the initial equality is somewhat better on open than on short circuit.

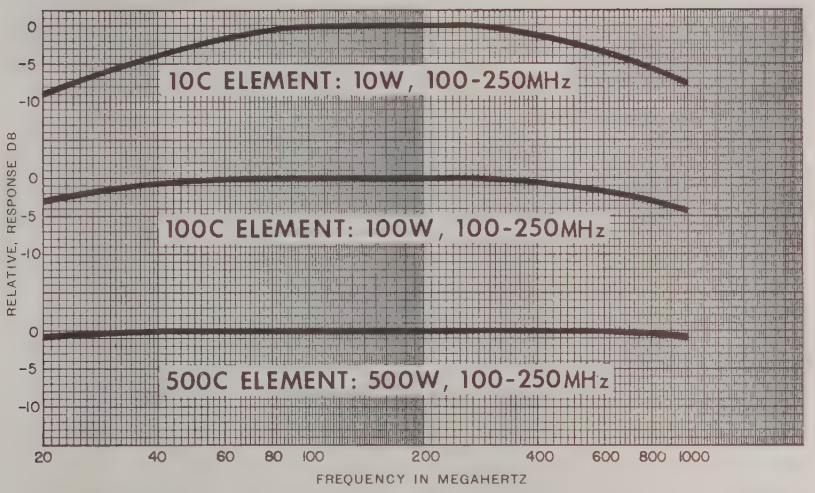
3-27. Again, for quite low values of measure attenuation, it is advisable to note exact readings, or difference, on the initial equality check, and to allow for this difference.

3-28. **FREQUENCY RESPONSE**

3-29. The Plug-In Elements have a very flat frequency response over a frequency ratio of more than 2½ to 1. This characteristic provides a practically flat response within the assigned frequency ranges for all the elements, see Tables 3-1.

3-30. An illustrative set of curves for three elements of one of these frequencies bands is shown in Figure 3-3. Notice that on the low power element, the fall-off above and below the assigned frequency band is more pronounced than it is for the high power element. The degree of drop in response varies progressively less for each power level from low to high, with the average difference at approximately

Figure 3-3. Representative Frequency Response.



the mean power level. These curves, Figure 3-3, may be assumed to be about typical for all of the listed band types (H, A, B, C, D, etc.) at their respective stated frequencies.

3-31. Harmonics, or subharmonics, may be known to exist in the measured circuit, outside of the element frequency band. If so, a rough approximation of the response of the element to these harmonics may be made by the use of these curves. The frequency ordinate to be read on the graph will be obtained by proportioning the frequency of the element used with that of the one illustrated. Interpolation of the curve values will give an approximation of the extent that these harmonic signals are being measured by your element.

3-32. The use of the elements for direct power measurements outside of their stated frequency range is not recommended.

3-33. **IMPEDANCE MISMATCH**

3-34. There may be cases where it is necessary to use the THRULINE® on other than the 50 ohm circuit for which it is desgined.

3-35. When using the THRULINE®, you will be inserting a four inch length of 50 ohm air line to the circuit, and the load on the transmitter will be changed from its original condition without the THRULINE®. For a power reflection factor under 10% and frequency below 200MHz, the four inch length mismatch is not too serious. But going any higher than these values, even if the transmitter is tuned up with the THRULINE® in place, the load impedance will be very different when it is removed.

3-36. The THRULINE® of course, indicates zero reflection when the load, at its load connector, is 50 ohms, pure resistive. An ideal condition on a 70 ohm line on the load side of the THRULINE® will show 3% reflected power; i.e., THRULINE®

load is 70 ohms resistive, VSWR in the 50 ohm THRULINE® is $^{70}/_{50} = 1.4$. The THRULINE® can also show this same reflected percentage with $^{50}/_{1.4} = 35.7$ ohms pure resistive load which could exist with 10% reflected power on the 70 ohm line (VSWR = 2 on the 70 ohm line). From this you can see that the 70 ohm line could have as much as 10% reflected power and VSWR = 2 when the THRULINE® indicates 3% reflected power of VSWR = 1.4.

3-37. It should be especially rememebered that with 70 ohm lines it is most important to get the reflected power indication and subtract it from the forward because of this factor being so much more critical here than with an intended 50 ohm line.

Table 3-1. Element Tables.

Table 1 - Standard Elements

	Frequency Bands (MHz)					
Power Range	2-30	25-60	50-125	100-250	200-500	400-1000
5W		5A	5B	5C	5D	5E
10W		10A	10B	10C	10D	10E
25W		25A	25B	25C	25D	25E
50W	50H	50A	50B	50C	50D	50E
100W	100H	100A	100B	100C	100D	100E
250W	250H	250A	250B	250C	250D	250E
500W	500H	500A	500B	500C	500D	500E
1000W	1000H	1000A	1000B	1000C	1000D	1000E
2500W	2500H					
5000W	5000H					

Table 2 - Low-Power Elements

1 Watt	Cat. No.	2.5 Watts	Cat. No.
60-80MHz	060-1	60-80MHz	060-2
80-95MHz	080-1	80-95MHz	080-2
95-125MHz	095-1	95-150MHz	095-2
110-160MHz	110-1	150-250MHz	150-2
150-250MHz	150-1	200-300MHz	200-2
200-300MHz	200-1	250-450MHz	250-2
275-450MHz	275-1	400-850MHz	400-2
425-850MHz	425-1	800-950MHz	800-2
800-950MHz	800-1		

Table 3 - High-Frequency Elements

Power Range	Frequency Bands (MHz) 950-1260	1100-1800	1700-2200	2200-2300
1W	1J	1K	1L	1M
2.5W	2.5J	2.5K	2.5L	2.5M
5W	5J	5K	5L	5M
10W	10J	10K	10L	10M
25W	25J	25K	25L	25M
50W	50J			
100W	100J			
250W	250J			

Table 4 - Low-Frequency Elements

Power Range	Frequency Band .45 to 2.5MHz
1000W	1000P
2500W	2500P
5000W	5000P
10000W	10000P

Table 6 - Milliwatt Elements

100mW	Cat. No.	250mW	Cat. No.	500mW	Cat. No.
72-76MHz	430-2	70MHz	430-34	72-76MHz	430-33
105-120MHz	430-6	72-76MHz	430-22	105-120MHz	430-26
136MHz	430-9	108-118MHz	430-24	240-290MHz	430-27
174MHz	430-10	130-150MHz	430-13	328-336MHz	430-28
328-336MHz	430-3	150-180MHz	430-15	455-470MHz	430-30
400MHz	430-7	328-336MHz	430-16		
470MHz	430-8	1700-1750MHz	430-17		

Special elements are also available; consult the factory.

3-38. For the convenience of users, a set of VSWR conversion nomographs is included in this instruction book. With these charts, VSWR's may be directly ascertained from forward and reverse power values read from the THRULINE® Wattmeter.

3-39. When a Model 43 is used to match a load to a transmitter and a good match is obtained, removing the instrument will not cause any change in the conditions, since a good 50 ohm load can be placed at the end of a 50 ohm transmission line of any length without altering conditions at the transmitter.

3-40. What happens when the load is not well matched, like an antenna with a VSWR of 1.5 or 2.0? Since the length of line between a mismatched load and the source transforms the impedance of the load as seen at the source, line length now becomes critical. If the adjustments for maximum power transfer were made with the Model 43 in place, removing it shortens the line by four inches, plus two con-

Figure 3-4. VSWR Conversion Nomograph.

Following the vertical and horizontal grid, determine intersection of forward and reverse power values. Slanted lines passing closest to this point indicate VSWR.

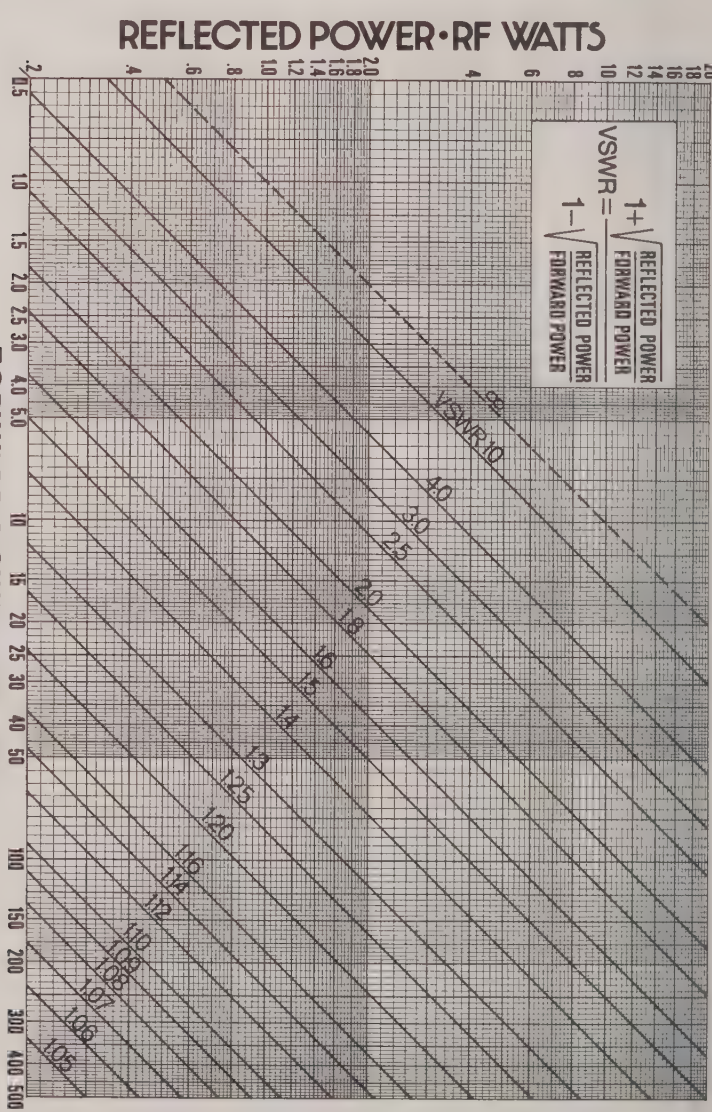
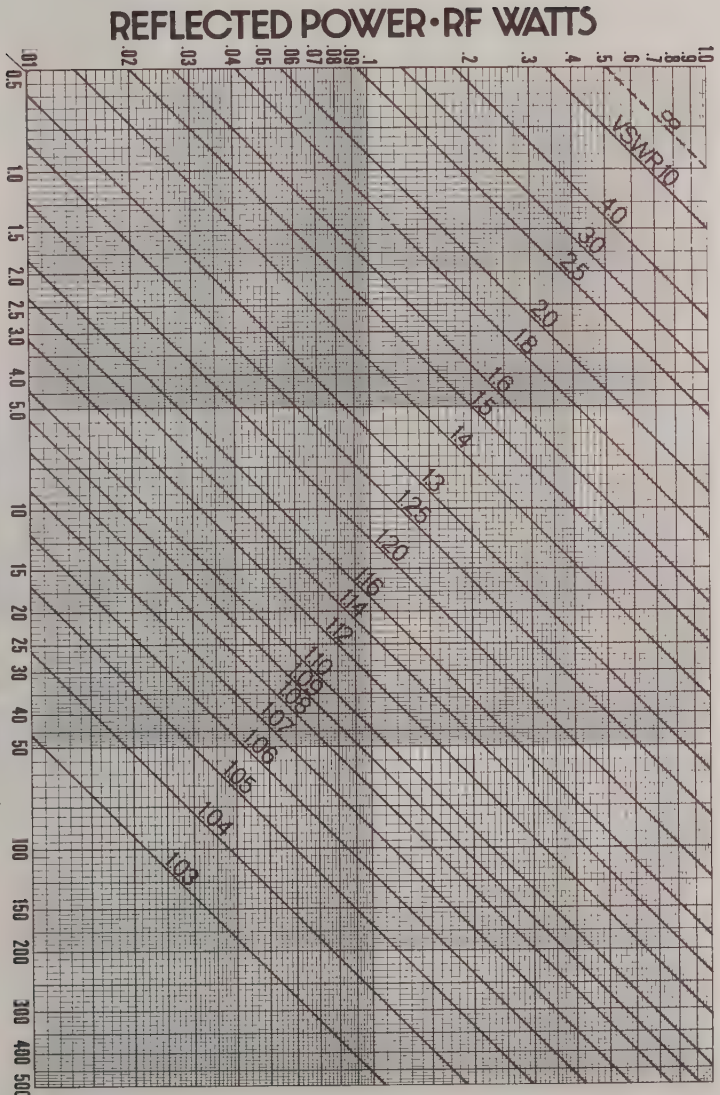


Figure 3-5. VSWR Conversion Nomograph.

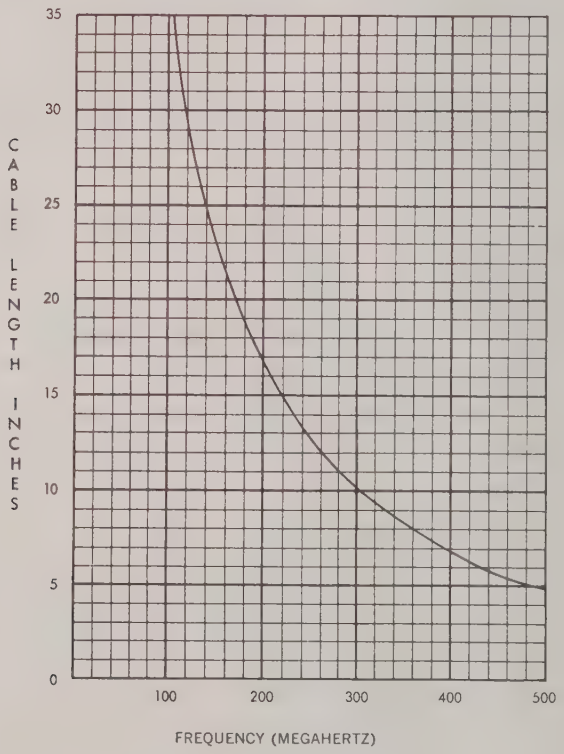


nectors. This still is no cause for concern at low frequencies where four to five inches is a small fraction of a wavelength. At higher frequencies; e.g., above 100MHz, power output and frequency of the source may be affected.

3-41. It is a principle of transmission line theory that the impedance is identical on either side of ½ wavelength. In order to duplicate the conditions in your transmission line with the Model 43 either in or out of the line, it is only necessary to insert or remove, a ½ wavelength.

3-42. This is easily done by making up a length of cable which, when added to the THRULINE® equals ½ wavelength at the frequency of measurement. If more than one frequency is involved, one cable is needed for each frequency.

Figure 3-6. Cable Wavelength Matching Graph.



Note:

1. When using UHF Plug 259 the cable length is measured from tip to tip of center pin of plugs.

2. When using other connectors the cable length is measured from end to end of outer conductor of connectors.

SECTION IV - MAINTENANCE

4-1. GENERAL

4-2. With the simple construction and generally self-contained nature of the THRULINE® equipment, there is only a moderate amount of maintenance required. One of the major precautions is in handling; use reasonable care and do not drop the THRULINE® equipment or the Plug-In Elements.

4-3. CLEANING

WARNING

When using dry cleaning solvents, provide adequate ventilation and observe normal safety precautions. Many dry cleaning agents emit toxic fumes that may be harmful to your health if inhaled.

4-4. The main factor in maintenance is care and cleanliness. The element socket should be kept plugged as much as possible to prevent the intrusion of dust. When a Plug-In Element is used for this purpose, use highest power element available, it should be positioned with the ARROW point upwards. This protects the meter and will not expose the element crystal to dangerous potentials if the RF line section should be energized. If any of the contacts or line connectors become dirty, they should be cleaned with a good contact cleaner or dry cleaning solvent on a cotton swab stick. Avoid excessive skin contact or inhalation of fumes when using. Observe special care if carbon tetrachloride is used. Clean all contact areas and especially the exposed faces of the teflon insulators.

4-5. It is particularly important to keep the mating surfaces of the socket and Plug-In Element clean. This applies to the bore of the socket and the circumference of the THRULINE® Element body, but most important to the bottom rim of the element body and the seat at the base of the socket in the line section. Also, check the ends of insulated dc contacts on the THRULINE® Element to see that they are clean and smooth. These parts should be carefully cleaned with a cotton swab stick and dry cleaning solvent. There must be a good contact between the base of the Plug-In Element and its socket to assure stable operation of the THRULINE®.

4-6. CONTACT ADJUSTMENT

4-7. In cleaning the socket bore, the operator should be careful not to disturb the spring finger of the dc contact. It is important that the operating position of this part be properly maintained. If the spring finger of the dc contact requires adjustment, it may be done manually if carried out with care. The button must be positioned far enough out to maintain good contact with the element, but not so as to interfere with easy entry of the element body. The dc jack, with spring finger, may be removed for access by unscrewing the two #4-40 fillister head machine screws which fasten it to the side of the RF line section. Then retract its assembly, watching carefully not to lose the small teflon positioning bead that straddles the base of the phosphor bronze spring and nests in a counterbore on the side of the RF body. When replacing the assembly, be sure that the bead is again properly inserted.

4-8. If there is any evidence of contamination inside the Rf line section, the reachable portions should be likewise wiped and the interior carefully blown out. Under no circumstances attempt to remove the RF center conductor. It is tightly frozen in place and any attempt to remove it will ruin the assembly. Keep all connections tight, and keep the nut of the meter cord plug turned tight on the line section dc jack. This connection may often be serviced by simply loosening the nut of the dc plug, swinging the body several times through a fraction of a turn, and retightening the knurled nut securely.

4-9. TROUBLESHOOTING

4-10. As a brief guide to the operator in isolating occasional difficulties that may occur in the use of the THRULINE®, the following summary is included. The remedies for same are referenced to the text in this section or are self-evident.

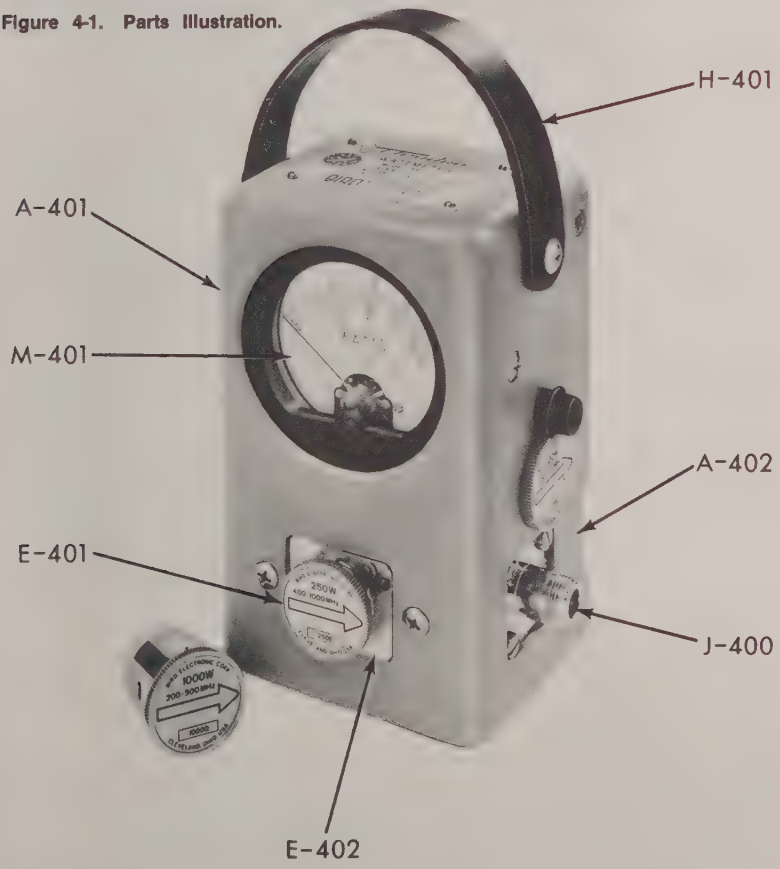
PROBLEM	POSSIBLE CAUSE	REMEDY
No Meter Indication	No RF power	Check RF source.
	ARROW on Plug-In Element pointing in wrong direction	Reposition element.
	No pick-up from dc contact finger	Adjust, see 4-6, Contact Adjustment.
	Open or short circuit in dc meter cable	Replace defective cable (RG-58/U).
	Meter burned out or damaged	Replace or return wattmeter to the factory for meter replacement and recalibration.
Intermittent or Inconsistent Meter Readings	Faulty transmission line or antenna	Inspect line.
	Dirty dc contact on elements	Clean, see 4-3, Cleaning.
	Sticky or defective meter	Replace or return wattmeter to the factory for meter replacement and recalibration.
High VSWR or Reflected Power	Bad load or poor connectors	Replace load, antenna or connectors.
	Shorted or open transmission line	Service or replace line.
	Foreign material in line section or in RF connector bodies	See 4-3, Cleaning.

4-11. CALIBRATION CHECKS - THRULINE® VS TERMALINE® WATTMETERS

4-12. It is recognized that calibration of absorption wattmeters is difficult and likely to be inaccurate unless comparison is made with a transmission, through, type of standard. The THRULINE® being of such type, a natural question is: Can a THRULINE® be used to check or recalibrate absorption wattmeters, such as the Bird Electronic Corporation TERMALINE®, both being rated at ±5% accuracy? The main question is one of exact power calibration.

4-13. The answer is a qualified yes, although with both instruments being about equally old and known to be undamaged, there is not too much reason to prefer either on probable accuracy. The edge is somewhat in favor of the THRULINE®, because each element covers only 2½ to 1 in frequency and will be flatter originally over this range than the TERMALINE® can be held initially over its very much wider, 16.7 to 1, frequency range. Also the THRULINE® will probably exhibit smaller changes with time, because of the narrower frequency range, because it is simpler in general design and easier in function (does not have to serve as a power load) and because it does not become heated in operation.

Figure 4-1. Parts Illustration.



4-14. Certainly if the absorption wattmeter has gone years since calibration, or is reasonably suspected of inaccuracy, it may well be calibrated against the THRULINE® as standard. Rather than use correction factors, one can, with the TERMALINE® Wattmeter, make use of the calibration adjustment screws used in factory calibration. These are concealed and not mentioned in the instruction book to discourage tampering. Consult with the factory if necessary.

4-15. If such calibration is undertaken, care and thoroughness are advised.

SECTION V - REPLACEMENT PARTS LIST

5-1. **MODEL 43**

ITEM	QTY	DWG REF NO.	DESCRIPTION	PART NUMBER†
1	1	A-401	Assembly, Housing	4210-018
2	1	A-402	Assembly, Cover	4210-005-1
3	1	E-401	Element, Plug-In	4250-020
4	1	E-402	Assembly, Line Section	4230-018
5	1	H-401	Strap, Carrying	8580-003
6	2	J-400	Connectors, RF	*See Below
7	1	J-411	Assembly, DC Connector	4230-010
8	1	M-401	Microammeter	2080-002
9	1		Replacement Meter Kit Consisting of: 1 Meter 2080-002 1 Assembly, Cable 4220-097-1 3 Bumper Feet 4220-098	8-000
10	1	P-401	Plug, DC Connector	7500-076
11	1	W-403	Assembly, Cable	4220-097-1

†When ordering please refer to these numbers.

*Available "QC" Type Connectors

N-Female	4240-062	LT-Female	4240-018
N-Male	4240-063	LT-Male	4240-012
HN-Female	4240-268	C-Female	4240-100
HN-Male	4240-278	C-Male	4240-110
LC-Female	4240-031	UHF-Female(SO-239)	4240-050
LC-Male	4240-025	UHF-Male(PL-259)	4240-179
BNC-Female	4240-125	7/8" EIA Air Line	4240-002
BNC-Male	4240-132		

SECTION VI - DIFFERENCE DATA SHEET

6-1. **MODEL 4430 THRULINE® WATTMETER**

6-2. General -

a. The Model 4430 RF Sampling Wattmeter operates the same as the Model 43 THRULINE® Wattmeter described in this instruction book in all particulars except for the extra provision of the special RF signal sampler probe equipment.

b. The general applications and maintenance procedures for the 4430 are the same as those of the Model 43. However, for instructions and specifications directly applicable to the Model 4430, the following information applies.

6-3. Installation - Same as for the Model 43 Wattmeter. Connect RF Sampler output with a suitable cable assembly, having a BNC plug and appropriate RF cable. UG-88E/U, UG-250D/U or equivalent plug, and RG-58C/U (50 ohm) or -59B/U (75 ohm) cable would be a common usage. The impedance of the sampler cable should properly match that of the monitoring equipment and be kept as short as conveniently possible.

6-4. Theory of Operation -

a. The RF Sampler, as its name implies, provides a low level signal or sample of the energy being transmitted through the line section of the wattmeter. This signal is available at a Female BNC connector located on the right side of the meter housing, labeled RF SAMPLE.

b. The signal output level is essentially flat at −53dB from 10MHz to 512MHz, tapering down below 10MHz to −70dB at 2MHz. This type of sample output serves to protect sensitive front-end circuits from unexpected overload and burnout.

c. The RF sampler probe device is fixed to the main line opposite the measuring element socket section and its output is fed to the BNC jack on the upper right hand side of the wattmeter housing. While operating the unit, this sampler output may be fed to any suitable RF signal monitoring device; i.e., frequency counter, spectrum analyzer, or oscilloscope, etc.

6-5. Maintenance - General maintenance procedures will apply to the Model 4430 the same as described for the basic Model 43 in this instruction book. Other processes pertaining to this model are:

a. To change the sampler probe remove the back cover, snap off button at top of probe block with a knife edge or sharp screwdriver. Take out the four #4-40 x ½ screws from the corners of the block, releasing it. The bayonet plug disconnects from the probe by pushing in first with a slight couterclockwise turn, then pulling out.

b. To remove the sampler output cable, use a suitable ⅝ flat wrench and unscrew the outside hex nut on the BNC jack; pull the cable out on the inside of the case.

c. This cable is best replaced in its entirety, if required. Its components can be changed by the usual procedures for the BNC and miniature cable plugs.

Table 6-1. Replacement Parts List - Model 4430.

ITEM	QTY	DESCRIPTION	PART NUMBER
1	1	Assembly, Wattmeter Housing (replaces 4210-018)	4430-011
2	1	Assembly, Line Section (replaces 4230-018) Consisting of:	4430-004
		1 Line Section, Modified 4230-006-3	
		1 RF Sampler Assembly 4430-007	
		1 Button, Snap 5-570-2	
		1 "QC" Female N Connector 4240-062	
3	1	Assembly, RF Cable Sampler Consisting of:	4430-002
		1 Cable (RG-58/U) 5-773-1	
		1 Plug, MB Connector, Male 5-245	
		1 Jack, BNC (UG-909/U) 5-953	
		1 Eyelet, Brass 5-414-1	

6-6. MODEL 4431 THRULINE® WATTMETER

6-7. General -

a. The Model 4431 RF Sampling Wattmeter is essentially the same as the Model 43 THRULINE® Wattmeter described in this instruction book in all particulars except for the extra provision of the special adjustable RF signal sampler probe equipment.

b. The basic operations and maintenance procedures for the 4431 are the same as those of the Model 43 as described in this instruction book. However, for instructions and specifications directly applicable to the Model 4431, use the following information:

6-8. Theory of Operation - The RF sampler, as its name implies, provides a low level signal or sample of the energy being transmitted through the line section of the wattmeter. This signal is available at a Female BNC connector located on the right side of the meter housing, labeled RF SAMPLE, and the level of this signal can be varied by means of the control knob located on the front of the meter housing. This adjustment is accomplished by means of a mechanical linkage connecting the sample adjustment (control) knob to the RF probe, so that turning the knob varies the proximity of the RF probe to the center conductor of the line section. Placing the probe closer (clockwise) to the center conductor increases the coupling and the signal level at the RF sample port, and moving the RF probe away from the center conductor (counterclockwise) decreases the coupling. See Table 6-4 for an approximate guide for the levels of coupling, and for a note on the maximum suggested adjustment of the sampler. In the operation of the unit, this sampler

output may be fed to any suitable RF signal monitoring device; i.e., frequency counter, spectrum analyzer, or oscilloscope, etc.

Table 6-2. Model 4431 - Coupling Data.

Frequency (MHz)	Maximum Sensitivity (Fully Clockwise)	Counterclockwise 4 Full Turns From Max. Position	Counterclockwise 7 Full Turns From Max. Position
2	69		
10	57		
25	46		
50	42		
75	39		
100	36		
200	31	38	
300		34	
400		30	
500		29.5	
600		29	
700		28.5	
800		28	36
900			35.5
1000			35

Note - It is important to decouple the RF sampler as indicated above for frequencies above 200MHz. The basic specifications of this instrument will be maintained with the above settings for the RF sampler. Decouple or turn counterclockwise beyond the above settings as much as possible, when possible.

6-9. Maintenance - The maintenance procedures for this model are essentially the same as for the Model 43 except for the inclusion of the variable probe equipment. It is not recommended that user make repairs on the probe assembly. If the sampler malfunctions, we suggest the unit be returned to the factory. Consult with the factory. If for a particular urgency, the user wants to make field replacement of the probe assembly himself, proceed in the following manner:

a. To reach the probe, remove the four #8-32 x $\frac{3}{8}$ Phillips flat head screws on the sides of the case near the back. Grasp the back cover firmly, by the tabs behind the line connectors, and pull straight backward to remove the back cover.

b. Use a $\frac{1}{16}$ hex socket Allen wrench to loosen and remove the small coupling control knob on the front of the wattmeter, just above the Plug-In Element socket. Remove the two #8-32 x $\frac{1}{4}$ pan head screws fastening the guide and movable plate assembly to the back of the line section. Restore the control knob to the front of shaft temporarily, and rotate the shaft counterclockwise until the threaded collar is free of the screw shaft and pull the movable probe plate straight out of the pin and guide bushing. Unscrew the $\frac{5}{8}$ hex instrument nut on the BNC connector (outside) and pull the sampler connector inside the case. The probe plate assembly, P/N 4431-003, is now released and may be replaced in its entirety.

c. The sampler cable (RG-58/U) solid wire center conductor is soldered to the rear stub of the probe piece itself. The cable is secured to the side sleeve of the probe with the same washer and screw parts used in the dc connector plug assembly, P/N 7500-076. It may be removed by unscrewing the threaded sleeve washer, 3/8 hex head, unsoldering the lead tip and pulling out the cable. The probe assembly is formed into the socket and is not replaceable.

d. Replace by carefully reversing the above procedure. Note - When inserting the threaded control bushing, be sure the alignment pin is properly positioned.

Table 6-3. Replacement Parts List - Model 4431.

ITEM	QTY	DESCRIPTION	PART NUMBER
1	1	Housing, Modified (instead of 4210-018)	4431-011
2	1	Assembly, Guide Plate	4431-002
3	1	Assembly, Movable Plate	4431-003
4	1	Assembly, Line Section (instead of 4230-018)	4431-004
5	1	Assembly, RF Cable Sampler Consisting of:	4431-030
		1 Connector, BNC Female 5-953	
		1 Cable, RF - RG58/U 5-773-1	
		1 Eyelet, for BNC Connector 5-414-1	
		1 Washer* 7500-074	
		1 Wedge* 7500-080	
		1 Seal* 7500-081	
		1 Screw* 7500-082	
		* Connector Parts for Probe Sleeve	
6	1	Knob, Sampler Control	5-1193
7	1	Meter, Cable, DC (instead of 097-1)	4220-097-8

6-10. SERIES 4520 THRULINE® WATTMETERS

6-11. General -

a. These Series 4520 RF THRULINE® Wattmeter units are essentially the same as the Model 43 Wattmeter, their electrical components and performance characteristics are alike. These models are panel mounted, for rack type installation instead of the all purpose portable housing of the Model 43 Wattmeter. Except for the Model 4527, which has an added feature of a Female BNC RF Sampler output connector on the panel, the data and operation contained in this instruction book is applicable to the Models 4521/22/23/25/26/27 in all respects, except as explained in the following:

b. These units are intended for fixed installation generally in rack mounts requiring 19" panels. According to each of the model types concerned, the various panels are punched out for the component arrangements involved.

The first line of the Replacement Parts List attached, lists (per Item A-405) the panel styles for respective Models 4521, 4522, etc. The remainder of this list carries the replaceable items for each model covered by this "Difference Data Sheet". From the parts list of Section V, only those items that are referred to in this attached parts list, apply herein. Figure 1-1, in the text of this instruction book is not applicable to these units, and Figure 4-1 applies only to the extent that the references M-401, E-401, E-402 and J-401 called out coincide with the parts list attached.

6-12. Installation - Four #12-24 machine screws fasten the wattmeter panel in the selected position on a relay rack, using the pattern of tapped holes regularly provided in standard racks. Choose a location for easy reading and operation of the wattmeter; try to place it where the coaxial cable lengths will be short and may be installed without sharp bends. In making connections, avoid the use of angles and adapters as much as possible. Make sure all cable plugs and connectors are screwed on securely.

6-13. Theory of Operation, Operating Instructions and Maintenance Sections-

a. Although the physical configuration of these models is different, the provisions in these sections of the 43 Instruction Book are fully applicable.

b. The Model 4527 is identical to the Model 4430 electrically, having an RF sampler port, and therefore, the specifications and sampler probe replacement instructions of the Model 4430 also apply to the Model 4527.

Table 6-4. Replacement Parts List - Series 4520.

ITEM	QTY	DWG REF NO.	DESCRIPTION	PART NUMBER
1	1	A-405	Panel, Mounting	
			(Comprises: M=meter, E=element socket, S=switch)	
			Model 4521 (1M, 1E)	4521-002
			Model 4522 (1M, 2E, 1S)	4522-006
			Model 4523 (1M, 1E)	4523-002
			Model 4525 (1M, 1E)	4525-002
			Model 4526 (2M, 2E)	4526-004
			Model 4527 (2M, 2E)	4527-005
2		E-401	Element, Plug-In	2450-020
			1 Model 4521/23/25	
			2 Model 4522/26/27	
			(Select per Tables)	
3	1		Assembly, Line Section	
		E-402	Model 4521/23/25	4230-018
		E-403	Model 4522/26	4522-002
		E-403	Model 4527	4527-002
4	1	J-400	Connectors, RF	See Section V - Replacement Parts List
5		J-411	Assembly, DC Connector	4230-010
			1 Model 4521/23/25 (Part of E-402)	
			2 Model 4522/26/27 (Part of E-403)	
6		M-401	Microammeter	
			1 Model 4521/22/27	2080-002
			1 Model 4523	2150-015
			1 Model 4525	2080-005
			2 Model 4526	2080-002
7	1	O-401	Knob, Switch Control (Model 4522 only)	5-709
8		P-401	Connector, Plug (Part of W-404)	7500-076
			1 Model 4521/23/25	
			2 Model 4522/26/27	
9	1	S-401	Switch, Rotary (Model 4522 only)	5-634
10		W-404	Assembly, Cable	
			1 Model 4521/25 (16"L)	4220-097-5
			1 Model 4522 (Harness)	4522-013
			1 Model 4523 (16.5"L)	4523-003-1
			2 Model 4526/27 (16"L)	4220-097-5
11	1	W-405	Assembly, RF Cable (Model 4257 only)	4430-002

†When ordering please refer to these numbers.

— NOTES —

QUALITY INSTRUMENTS FOR RF POWER MEASUREMENT

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